SCIENTIFIC AND TECHNICAL JAPANESE

A STUDY OF ITS EFFICIENCY AS A MEANS OF COMMUNICATION, WITH AN ANALYSIS OF THE JAPANESE TECHNICAL VOCABULARY AND PRACTICAL SUGGESTIONS FOR TRANSLATORS

by

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New York, 1944

PREFACE

The present study is the result of several years' reflection on a difficult field. It is of course true that the question of "efficiency" constitutes a very limited and one-sided approach to the problem of language. But for science and technology the question of efficiency, whether of the machines and tools used or the methods applied, is of the greatest importance. Language is one of the primary tools of the working scientist or engineer; as such it must submit to the same analysis and appraisal as his other machines.

The main purpose of this work is clearly indicated in its title; it purports to study the efficiency of scientific and technical Japanese as a means of communication. As such, I believe it presents a novel approach to some of the problems of Japanese language work. But while it is chiefly concerned with a particular language, it also introduces a general method of attack which, I hope, will be found sufficiently useful and suggestive to warrant its application to other languages as well, both European and non-European.

At the same time I believe this booklet should prove very useful to the student grappling with the stiff practical problem of translating technical Japanese. The analysis of the Japanese technical vocabulary and the suggestions for translators are the product of many years of work in the field both as technical translator and as lexicographer. To the best of my knowledge, this is the first study devoted to the theoretical and practical questions

connected with scientific and technical Japanese. As such it is undoubtedly characterised by the normal deficiencies of a first effort in an abstruse and isolated field.

Finally, I would like to acknowledge the work of the Chinese Printing Office at Yale University under Professor George Kennedy and Mr. Pasquale De Rosa in the mechanical preparation of the manuscript for publication.

Stanley Gerr

New York City, February 1944

CONTENTS

INTRODUCTION

In an earlier study ("Language and Science": Philosophy of Science, Vol. 9, No. 2, April, 1942) I developed the thesis that the language of science is necessarily characterized by two main features: rational syntax, and a "functional" vocabulary. The first of these was understood to imply the use of a simple, logically unequivocal sentence structure in which syntactic elaboration had been reduced to the minimum required for efficient and convenient exposition; the second the extensive use of "functional" or "operational" terms.

"Functional" or "operational" terms were explained as representing the coalescence of "nominal" (i.e. structural or descriptive) and "verbal" (functional, operational, dynamic) significance in a single basic symbol or expression, as in a saw "saws", a pump "pumps", or say, $\int f(x)dx$, in which the symbol of integration $\int$ might be interpreted in a "nominal" sense--the "integral" of some $f(x)dx$ --or as a sort of verbal "imperative"--integrate $f(x)dx$--depending on the context. At the same time it was asserted that the extensive use of such "functional" expressions revealed the fundamental scientific urge to correlate--or even identify outright--"structure with behaviour, form with function, ultimately matter with energy"; moreover, that the linguistic counterpart of this tendency on the part of science and technology to identify an operation or process with its means of realization is precisely the development of these "operational" or "functional" terms.

These concepts of "rationality" and "functionality" of expression provide us with the criteria for an appraisal of language as a scientific and technical "tool". For it is to the extent that a particular language systematically incorporates these features in its scientific and technical "dialect" that it may be said to satisfy the basic engineering requirement of all "tools": efficient and economical operation. Sapir, in his book on "Language", has well said: "Were a language ever completely "grammatical" (i.e. systematic) it would be a perfect *engine* of conceptual expression." And for the purpose of appraising its efficiency and economy of operation the language of science and technology may be conceived as a sort of transportation system in which a certain expenditure of mental and bodily energy--"linguistic energy"--effects the transmission of a certain group of concepts from person to person.

The measure of its "efficiency" would then be the ratio of "achievement" (concepts communicated or transmitted) to "energy-consumption" (convenience and simplicity of linguistic formulation and ease of interpretation by reader or hearer). Accordingly, an efficient language, in the strictly technical sense of the word, would be one in which there was a small consumption of "linguistic energy", corresponding to rational simplicity, convenience, and conciseness of formulation, and ready and rapid communication of the ideas with a minimum loss of "conceptual cargo" corresponding to accuracy, exactitude, and precision of expression. It must not only convey the writer's meaning accurately and fully, but it must do this with a minimum expenditure of mental and physical energy on the part of both author and reader. For science and technology language must be stripped of all grammatical superfluities and

psychological hindrances to ready and efficient fulfillment of its communicating or "transporting" functions. It must, as far as possible, conserve mental energy for concentration on the actual concepts involved in the discussion, rather than dissipating energy, time, and attention on unnecessary consideration of the linguistic or symbolic forms in which the ideas are presented. Whitehead, discussing the great advantage of a proper symbolic technique in his "Introduction to Mathematics", says: "By the aid of (proper) symbolism we can make transitions in reasoning almost mechanically by the eye, which otherwise would call into play the higher functions of the brain.....Operations of thought are like cavalry charges in a battle--they are strictly limited in number, they require fresh horses, and must be made at decisive moments."

In this study it is proposed to apply these concepts and criteria to an appraisal of scientific and technical Japanese, in the hope that the results of the inquiry may be of some value in promoting among us a belated understanding of the strange language in which a considerable body of important research and technical information is recorded in the profuse technical literature of Japan. It is perhaps not too far-fetched to assert that gross neglect of this field in the past has been a contributory cause of the difficult and dangerous situation in which we as a nation now find ourselves: battling an adversary whom we have neglected to appraise carefully in terms of several of his most important military aspects: his science, technology, and industrial development.

PART I: PROBLEM OF JAPANESE SYNTAX

The problem of scientific and technical Japanese has three major aspects: the questions of Japanese syntax, the technical vocabulary, and the complex script. While the first and last of these are common to the whole of written Japanese, the problem of the technical vocabulary is more or less peculiar to the language of science and technology. Accordingly, we turn first to the question of Japanese syntax in its bearing on the *efficiency* of the language as a scientific and technical "tool".

Syntax, it will be recalled, deals primarily with the systematic way in which a language combines and relates the objects and elements of a discussion into psychologically unified propositions called sentences; i.e. with the *mechanics of sentence structure*. As Sapir (Language) puts it, the sentence is "the major functional unit of speech". In connection, then, with Japanese sentence structure, I believe it is safe to assert from the start that the language suffers from certain basic structural defects which seriously impair its effectiveness as a scientific means of communication. These are the excessive length and diffuse, protracted complexity of the sentence which, as Chamberlain (Japanese Grammar) has it, makes "the normal Japanese sentence a paragraph"; the rigidly observed and abnormally sustained Japanese word-order, which without exception requires *all modifiers*, however complex and however numerous, to precede the words or concepts they qualify, while relegating the all-important verb to the very end of the statement; the use of certain "indefinite" verb and predicate adjective forms in compound sen-

tences; the frequent omission of the subject of a sentence; and the excessive use of grammatically and logically superfluous stylistic embellishments. We proceed, then, to further consideration of the ways in which these factors lower the overall efficiency of Japanese as a means of communication, and therefore as a technical "tool".

Our first quarrel is with Japanese word-order. Now word-order, the order of presentation of ideas, is fundamental. Sapir (Language: p.117) states emphatically, that "The most fundamental and the most powerful of all relating methods (within the sentence) is word-order." Nor are other philologists less positive than Sapir in accenting this point (cf. Jespersen, Paul, etc.). Hence our first step in proving our contention that Japanese suffers from certain basic structural disabilities as a means of efficient communication of technical ideas will be to demonstrate that Japanese word-order is such as to materially hinder and delay ready comprehension of the writer's meaning.

As was stated above, the cardinal rule of Japanese syntax, including, of course, that of scientific and technical Japanese, is that *all* modifiers must precede the words or expressions they qualify, and that the verb must appear last in the sentence or clause. Quoting Chamberlain once more, "every adjective, genitive, or attributive word, phrase, or clause precedes the noun which it defines, the adverb precedes the verb, and explanatory clauses precede the principal clause". Or, as G.B. Sansom (Historical Grammar of Japanese, p. 335) puts it: "The characteristic feature of word-order in Japanese is that the particular precedes the general".

Now most attributes--or "particulars"--are less determinate than tangible objects, the

"realia" of science and technology, and, in fact, depend on them for concrete significance. For example, when I write "a large, bluish, glittering, northern, recently discovered, as yet unclassified, etc. etc.", none of these words or expressions can assume specific, concrete meaning, since their immediate significance depends largely on the context in which they appear, or, more explicitly, on the object or entity they refer to--in Whitehead's phrase, on the particular "universe of discourse". Each of the above expressions will take on a somewhat different significance if I add to the above the word "star", say, on the one hand, or "moth" on the other. Most attributes or descriptive concepts are purely relative, taking their coloring, so to speak, from their immediate environment (cf. hard, weak, etc.). In fact, the number of "absolute" attributes is quite small, and is largely restricted to the field of mathematical and physical concepts, as "triangular, circular, integral, crystalline, etc." But the great bulk of descriptive ideas do not belong to this category; for them a definite object or universe of discourse must be postulated before they can assume concrete, specific significance.

This has serious consequences for the type of sentence structure represented by Japanese, which rigidly requires all modifiers in a sentence to precede the objects modified, and which at the same time favors long descriptive statements. For as Pillsbury (Psychology of Language, p. 268) points out: "one can attend to only one object (idea) at once, and the duration of attention is less than one second". Hence the highly synthetic constructions of Japanese frequently delay mention of the actual objects of discussion well beyond the point where corresponding modifiers are conveniently and

spontaneously linked with the more concrete entities which they qualify, and which in turn provide them (the modifiers) with a sort of scale of reference or measurement for the situation under discussion, For it is a peculiar fact that modifiers are themselves unable to modify concretely till the entities they qualify are themselves established, so that in actuality a modifying attribute must itself first be qualified by the modified object before it can properly modify at all. In the language of logic, "modifying" is a *reflexive* and *symmetrical* relationship. Under these circumstances the Japanese sentence is revealed as basically inefficient, since, as was just pointed out, its structure so frequently prevents its modifying elements from functioning--i.e. modifying "concretely" --till long after they have appeared in the statement; i.e. till the objects they qualify are eventually revealed. Consequently the reader of Japanese is generally forced to reinterpret the descriptive parts of a sentence several times in order to establish their specific significance in the particular context fixed by mention of the objects of discussion well after the appearance of the modifiers themselves.

The preceding, rather theoretical discussion will perhaps become clearer if reconsidered in the light of the following examples. These have been chosen from typical Japanese technical source material, as is likewise true of other examples which appear further on. In all cases the original Japanese text, a *Rōmaji* version, a literal translation giving the exact sequence of ideas, and a final version in standard technical English have been given, so that the reader should experience no great difficulty in making the proper associations between the points raised in the text of the dis-

cussion and the corresponding examples. Thus 電氣工學ポケットブック : *Denki-Kōgaku Poketto-bukku:* (Electrical Engineering Pocketbook) (1934) p. 45, defining Coulomb's law, has the following statement:

二箇の點電荷q_1,q_2が距離, rを隔てゝ存在する時,兩者の間にはq_1,q_2の相乘積に比例し, rの自乘に逆比例する力が作用する.

Ni-ko no ten-denka q_1, q_2 ga kyori r wo hedatete sonzai suru toki, ryōsha no aida ni wa q_1, q_2 no sōjōseki ni hirei shi, r no jijō ni gyaku-hirei suru ryoku ga sayō-suru.

Two piece point electric charge q_1, q_2 distance r separating existing time, both ones betweenness in q_1, q_2's direct product to proportional being, r's square to inversely proportional being force acts.

When two point electric charges q_1, q_2 are separated by a distance r, a force acts between them which is directly proportional to the product of these charges, and inversely proportional to the square of r, the distance between them.

Again, the following explanation of "optical inversion" is given in a book on mineralogy:

光學的轉化は旋光性の同質異性體の一より同一構造を有するも反對の旋光性を有する他のものに變化することである.

Kōgaku-teki tenka wa senkōsei no dōshitsu-isei-tai no ichi yori dōitsu kōzō wo yū-suru mo hantai no senkōsei wo yū-suru to no mono ni henka-suru koto de aru.

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Optical inversion now (as for) optically active isomers one from same composition having but opposite optical activity having other one into turning action is.

Optical inversion is the conversion of an optically active isomer into another with the same constitution but reversed optical activity.

Returning to the discussion, it is to be observed that if the number of modifiers in an expression is small--say two or three--the object modified is mentioned so soon that the above argument hardly applies. Thus an expression like "long, round tube" is neither psychologically or linguistically inefficient because the space and time interval between mention of the first modifier and the object of discussion--"tube"--is small enough for the whole to blend in an integrated mental image, somewhat as a series of visual impressions occurring within a certain limiting time-interval of each other present a uniform, continuous image in the well-known phenomenon of persistence of vision. But if the number of modifying ideas is too great--psychologically more than three or four --the immediate continuity begins to disintegrate, necessitating a return to the beginning of the statement for a reestablishment of the thread of discourse.

English, for example is well aware of the psychologic need to fix the immediate universe of discourse as soon as possible by mention of each object of discussion as it arises. Although short, concise expressions like "long, elliptical tube" are common enough and quite acceptable, when the number of qualifying attributes becomes so large as

to require an excessive expenditure of "linguistic energy" to retain them consciously in view till the object they modify is finally mentioned, English--and most European languages--shifts the latter strategically into the midst of the qualifying expressions. In this way it is reached soon enough to concretize the first few modifiers before they have "faded", while the rest of the statement proceeds naturally and unambiguously to its conclusion because the object of discussion has been established. In the hypothetical example cited above scientific English would accordingly tend to a form like "a large, bluish, glittering northern star (moth), recently discovered but as yet unclassified, etc."

But this is precisely what Japanese cannot do. In the first place, the syntax of the language requires *all* modifiers, without exception, to precede the objects modified. This, as was indicated above, would not be serious if their number were always small (three or four); i.e. if Japanese sentences were normally short and concise. Unfortunately, this is rarely the case. As Chamberlain (Japanese Grammar) has it: "one of the most essential characteristics of the Japanese language is the extreme degree to which it pushes the synthetic tendency in the structure of sentences. Except when modified by Chinese or other foreign influences, Japanese always tries to incorporate the whole of a statement, however complex it may be, and however numerous its parts, within the limits of a single sentence whose members are all grammatically interdependent. In fact, the normal Japanese sentence is a paragraph". Sir G B. Samsom, in his Historical Grammar of Japanese, makes the same point: ".....the fundamental structure of Japanese

is such that, even with the best intentions, long sentences cannot always be avoided". This is putting it mildly, the fact being that short, summary sentences are the exception rather than the rule.

This, however, coupled with the rigid rules of word order mentioned above, is fatal to the *efficiency* of the language as a means of communication. For any object (or operation) mentioned is almost invariably preceded by a whole series of modifiers (qualifying words and phrases) none of which can be clearly conceived till the object of discussion is itself finally mentioned. Only when the latter has been reached does the preceding context acquire specific meaning, and only then, so to speak, do the preceding modifiers properly fulfil their function: i.e. "concretely" modifying the object of discussion. Hence the full and immediate significance of the qualifying expressions remains in abeyance till the object modified is established, which fact then necessitates a revaluation of the modifiers in the light of the universe of discourse revealed by the mention of the object of discussion, and then a revaluation of the latter in the light of the now concretely established modifiers. This involves what might be called, mathematically, a "semi-infinite regression".

The following two examples are illustrative of the preceding argument, the first being a descriptive passage taken from a larger context, the second a typical Japanese technical sentence:

金屬箔を絶緣紙を重ねて卷いて作つた固定蓄電器……

Kinzoku-haku wo zetsuen-shi wo kasanete maite tsukatta kotei chikudenki...

Metal foil and insulating paper together repeatedly winding made fixed condenser...

A fixed condenser made by repeatedly winding together metal foil strips and insulating paper...

船體強弱學: *Sentai Kyōjaku-gaku:* The Strength of Ships, by Tomoya Ōta, 1939: p. 79: 船と波との相對位置: *Fune to Nami to no Sōtai-ichi:* The Relative Position of Ship and Wave:

基準計算は既述の如く,船が自長の同長の波に,而も其の中央横斷面が波頂(又は波底)と一致する様に乘つた場合に於ける屈曲モーメント及び剪斷力を與へて異れるのであるが,波も船も絶えず進行してゐるのであるから,船と波との相對位置如何に依つては,或は基準狀態よりも大なる屈曲モーメント及び剪斷力が起るかもしれぬ.

Kijun keisan wa kijutsu no gotoku, sen ga jichō no dōchō no hami ni, shikamo sono chūō ōdammen ga hachō (mata wa hatei) to itchō-suru yō ni notta baai ni okeru kukkyoku-mōmento oyobi sendanryoku wo ataete kureru no de aru ga, nami mo fune mo taezu shinkō-shite iru no de aru kara, fune to nami to no sōtai-ichi ikan ni yotte wa, aruiwa kijun jōtai yori mo dai-naru kukkyoku-mōmento oyobi sendanryoku ga okiru ka mo shirenu.

Standard calculations as for already stated like, the ship its own length that same wave length's wave in, and its central cross section the wave crest (or wave trough) that in harmony fashion riding instance in's bending moment and shear stress being given

are but, wave and vessel ceasing-not advancing are because, ship and wave's relative position in what way depending on, perhaps standard conditions than even greater bending moment and shear stress arise whether known-is not.

As has already been stated, the bending moment and shear stress are given in the standard calculations for the two cases where, the length of the ship and that of the waves being equal, either the crest or the trough of a wave is amidships. However, since both ship and wave are continually advancing, it is not known whether even greater bending moments and shear stresses than those of the standard conditions are produced depending somehow on the relative position of ship and wave.

A somewhat similar defect arises in connection with the peculiar syntax of the Japanese verb and closely related predicate adjective. To begin with, in simple sentences the verb invariably appears after the object at the very end of the whole sentence; while in the lengthy compound sentences so common to Japanese various subordinate verbs are placed at the end of their respective subordinate clauses, the main verb appearing as before at the very end of the whole statement, supplying the final clue to the meaning of the whole. Thus the more or less standard Japanese word-order is, in the large, an introductory phrase or expression, the subject (if expressed at all, which it frequently is not, adding another element of ambiguity to the whole), preceded by all its modifiers, the object, preceded by all its modifiers, and finally the verb, with its modifiers. Or, in the case of

the compound sentence, the subject of the whole, if expressed, various clauses with their respective subordinate verbs at the end of each clause, the object of the whole sentence, and finally the verb. This type of sentence structure results, then, in an intolerable delay in the expression of the fundamental "operational" meaning of the whole statement, with a corresponding delay, as well as a vastly increased difficulty, in the reader's comprehension both of the whole sentence, and of the subordinate parts.

But not only is the "dynamic, operational" significance of the statement delayed by the subordinate position of the verb, the whole positive or negative significance of the statement, which is expressed by a negative particle suffixed to the verb--i.e. at the very end of the sentence--also remains indeterminate till the very end of the utterance. Thus one never knows whether the author is affirming or denying something till "the last returns are in", so to speak. The following examples, taken from Prof. Tachū Naitō's 耐震構造論 *Taishin Kōzō Ron:* Theory of Earthquake Resistant Construction, as well as those cited elsewhere in this study, serve to illustrate the point under discussion.

p. 38:

普通想像せらるゝ如く中軸線よりの距離に比例し(A)線の如くなることなく,却つて外側の柱と次の柱との反力は符號相反することゝなる.

Futsū sōzō-serarurū gotoku chūjiku-sen yori no kyori ni hirei-shi (A) sen no gotoku naru koto naku, kaette gaisoku no chū to tsugi no chū to no hanryoku wa fugō sōhan-suru koto to naru.

Generally believed as is neutral axis's distance to directly proportional being (A) line similar being thing not being, but on the contrary outside column and next column's reaction sign oppdsing fact is the case.

Contrary to what is generally believed, they (direct stresses in the supporting columns of certain types of framed structures) are not directly proportional to the distance from the central axis as in the case of line (A), but on the contrary the reactions of the outside column and the inner one immediately next to it have opposite signs.

p. 77 (same source)

抑も剪力の分布均一なりと云ふことゝ直應力が中軸よりの距離に比例すと云ふことゝは一般の梁に於ては兩立せざる事項なりとす.

Somo senryoku no bumpu kinitsu nari to iu koto to choku-ōryoku ga chūjiku yori no kyori ni hireisu to iu koto to wa ippan no ryō ni oite wa ryō-ritsu-sezaru jikō nari to su.

Now shear's distribution uniform being that said thing and direct stress neutral axis from's distance to direct proportion being that said thing as for ordinary beams in incompatible particulars (factors) being that is.

The fact is that uniform shear distribution and direct proportionality of axial (direct) stress to the distance from the neutral axis are incompatible conditions in ordinary beams (as mounted in framed structures).

Moreover, in compound sentences the verb--or predicate adjective--of each clause is used at the end of each corresponding clause in an incomplete form called by Europeans the "indefinite" form, by

the Japanese the "renyokei" or "continuative form", in which guise such vital elements of significance for the precise meaning of the whole statement as tense, mood, and attributive function are not indicated at all. In this way the full and precise meaning of each subordinate verb or predicate adjective is withheld till the very last verb or predicate adjective in the series of clauses is given with specific connotation in regard to these aspects. Only when these elements of significance have been established for the main verb do the preceding "indefinite" verbs assume their definitive form for the particular statement by taking on the same tense, mood, etc. as the final verb. But until the latter is reached at the very end of the sentence, the precise significance of each subordinate verb and predicate adjective must remain in abeyance. As Sansom (Hist. Gram.) has it: "the normal position of the Japanese verb at the end of the sentence makes for.....a lack of emphasis".

Once again, this is putting it mildly, to say the least. From the point of view of *efficiency of communication* this factor in the Japanese sentence structure represents a maximum waste of both author's and reader's mental energy. Once again, as in the case of the nominal constructions, the reader is forced to retrace his steps, often enough, not once but several times, adding the final bit of necessary information which is gleaned only at the very end of the statement, but which is absolutely indispensable for proper comprehension of the preceding sections as well. Thus this inherent ambiguity in the syntax of the Japanese verb and predicate adjective, which more or less constitute the "backbone" or "framework" of the Japanese sentence, is found to be very similar to that of the nominal constructions, and produces the same type of 'lin-

guistic inefficiency": viz. the need to backtrack over ground already covered.

It is interesting to note that this use of the indefinite form of the verb and predicate adjective in Japanese resembles, in a sense, the common technique of factoring out common elements of complex algebraical expressions. But where in mathematics this technique is a very useful expedient both as a labor-saving device and as revealing the underlying forms of complicated mathematical expressions, in Japanese the same practice becomes a gross liability. This is because the mathematical technique is applied to a compactly juxtaposed expression which is *visually assimilated as a unit*, whereas Japanese sentence structure so widely separates the related elements that it is impossible to literally "take them in at a glance", so that comprehension is materially delayed rather than speeded up. That is, an essentially *visual technique* is applied to a *phonetically designed symbolism*, with dire consequences for the latter. Moreover, "such constructions are of fundamental importance in Japanese syntax, and it is impossible to understand the written language until they are thoroughly mastered" (Sansom: loc. cit. p. 139). Hence they represent a fundamental source of inefficiency for the language.

Similarly, questions in Japanese are not structurally differentiated from ordinary affirmative statements until the very end of a sentence, where an arbitrary particle, "ka" or "ya", is generally added to indicate the "question". This is not as serious as the corresponding fact regarding *negative* sentences only because "questions" are rather infrequent in technical Japanese; but it is an added factor of inefficiency in a language which

is already overburdened with serious grammatical difficulties.

Thus the order of presentation of ideas in Japanese appears to be basically inefficient from the point of view of the psychology of language. Japanese syntax attempts, so to speak, to add the architectural details and embellishments before the foundation and framework of the building have been properly set up. Its sentences are "turned around", and, as everyone with experience in translating Japanese knows, are much easier to render into intelligible English if "attacked from the rear", where are found the key words and expressions which establish the objects of discussion and the operations they perform, or the changes they undergo. Being forced, by its innate syntactic pattern, to place key words and meanings in psychologically subordinate positions, it displays, in place of a psychological progression in which the antecedent clarifies the consequent, the strange order in which the end reveals the beginning. The Japanese sentence is thus seen to be a sort of miniature "detective story", which, like its better known counterpart, too often leaves its reader in a fog till the bitter end. One is forever forced, in translating technical Japanese, to make frequent passages up and down the line of the whole sentence in order to piece together the scattered ideas in their proper relationships; to waste mental energy in traversing the same linguistic "path" several times in order to complete a single, corresponding passage along the chain of ideas under consideration. To say the very least, Japanese sentence structure is thoroughly inefficient from the point of view of a "transportation system", as it most effectively prevents the ready and convenient communication of ideas.

A third source of inefficiency is less fundamental than the preceding two, being stylistic rather than syntactic. This is the excessive use of stylistic embellishments by means of grammatically and psychologically superfluous elements and expressions such as "nakereba naranu" (ought, must), "koto de aru" (is), etc. Such roundabout expressions, the meaning of which can always be given more concisely, are nevertheless very common in Japanese. By complicating still further the already hyperambiguous, cumbersome mechanism of expression, these "elegant" circumlocutions represent a final source of inefficiency in the Japanese linguistic "transportation system", since additional mental and physical energy must be expended in first assimilating, then rejecting them as logically irrelevant or superfluous to the argument.

In illustration of the points just mentioned, and by way of providing additional material illustrative of the whole preceding discussion, the following examples are added.

Naitō: loc. cit., P. 3:

横力に對し架構に起る曲能率並に應力の算定は架構設計に必要なる唯一のものにして, 風壓地震等に對し充分の強度と工費の低廉とを欲せば,必ずその設計の始めに於て完全ならざるべからず.

Ōryoku ni tai-shi kakō ni okoru kyoku-nōritsu narabi ni ōryoku no santei wa kokō sekkei ni hitsuyō-naru yuiitsu no mkno ni shite, fūatsu jishin nado ni tai shi jūbun no kyōdo to kōhi no teiren to wo hosseba, kanarazu sono sekkei no hajime ni oite kanzen narazaru-bekarazu.

Lateral forces to corresponding framed structures in arising bending moments and stresses calculations as for framed structure design in important being number one fact being, wind pressure, earthquakes, etc. to corresponding sufficient strength and construction's low cost that if desiring, certainly design's beginning at perfected not being must not be.

The calculation of bending moments and stresses in framed structures due to lateral forces is the most important factor in the design of such structures, while if these structures are to have sufficient strength to withstand wind pressures, earthquake shock, etc., as well as low cost of construction, these factors must be completely accounted for right from the start of the design.

Same source, p. 240:

大森博士は最近各種建築物の自己振動を驗測せられ其の振幅の大小及週期の長短は建築物の耐震的價値或は剛強の度合を表はすものとの論をなされたり.

Omori hakushi sakin kakushū kenchikubutsu no jiki-shindō wo kensoku-serare sono shimpuku no dai-shō oyobi shūki no chōtan wa kenchikubutsu no taishin-teki kachi aruiwa gōkyō no doai wo arawasu mono to no ron wo nasaretari.

Omori doctor recently various types of buildings' natural vibration investigated, their vibration-amplitudes' "big-small" and periods' "long-short" buildings' resist earthquake value or rigidity degree demonstration that discussed.

Dr. Omori has recently investigated the natural vibrations of various types of buildings, and has pointed out that the amplitude and period of vibration express the quake-resistant strength or degree of rigidity of such structures.

新粒子論: *New Particle Theory*: by Hideki Yukawa: p. 3, discussing the magnetic moment of the atomic nucleus:

これに反して,核内に電子が存在するならば,その磁氣能率は,ある場合には Bohr 磁子 $\mu_0=eh/2mc\fallingdotseq 1850\mu_N$ の程度になる筈であるが,この様な核は未だ見つからない.

Kore ni han shite, kakunai ni denshi ga sonzai-suru-naraba, sono jiki-nōritsu wa, aru baai ni wa Bohr jishi $\mu_0=eh/2mc\fallingdotseq 1850\mu_N$ *no teido ni naru hazu de aru ga, kono yō na kaku wa imada mi-tsukaranai.*

This contrary to, nucleus within electron(s) exist if such there be, their magnetic moment now, such a case in, the Bohr magneton $\mu_0=eh/2mc\fallingdotseq 1850\mu_N$ *amount proportion in should be, but that type of nucleus as yet observed has been not.*

On the contrary, if electrons were present in the (atomic) nucleus the magnetic moment should be of the order of the Bohr magneton $\mu_0=eh/2mc\fallingdotseq 1850\mu_N$, but such a nucleus has not yet been observed.

These three features, then, all serve to impair the communicating efficiency of scientific and technical Japanese. The first two are basic--inherent in the structure of the Japanese sentence. Thus the abnormally sustained synthetic word order and the use of the "indefinite" or "continuative" verb and predicate adjective forms set permanent

limits to the overall effectiveness of the language, and constitute, together with the difficulties of the complex script and the technical vocabulary, a tremendous "minimum burden", both mental and physical, which the Japanese intellectual worker must bear. As for the stylistic embellishments mentioned above, they could quite conceivably be eradicated from the scientific and technical language with some slight mitigation of the difficulties of expression and interpretation, but compared with the exhausting influence of the basic structural defects, this represents a very minor improvement at best.

Fundamentally, the trouble with Japanese is that the sentence structure withholds vital information till the end of the statement, the respective objects of discussion being relegated to secondary positions, while the basic *action* of the context is concealed till the very end, all of which results in an inescapable vagueness and ambiguity of the whole formulation. For the purposes of science and technology language--as any other tool or instrument--must operate with maximum efficiency. Superfluous elements must be eliminated, and the essential remainder must be formulated in the simplest manner consistent with the efficient performance of the allotted task--the communication of ideas. In so far as the structure or syntax of Japanese is concerned, it must be said to violate the basic engineering requirement of "efficient functioning", since it compels us to traverse the same linguistic path several times in order to attain a degree of understanding which, in a more logical word-order, should come from a single passage along the "linguistic transportation system". Since Japanese conspicuously fails to achieve this,

on the score ot its structure alone it must be rated as thoroughly inefficient, wasteful, and inadequate for the purposes of scientific and technical communication.

The question then arises: if Japanese is indeed as cumbersome and inefficient as it appears to be, how is it possible for the Japanese scientist and engineer to formulate his thoughts with any degree of clarity and precision, and to express them adequately? How have they been able to offset the crushing burden of the irrational Japanese "idiom" they are forced to use? The answer lies in the nature of the Japanese technical vocabulary, which, based on written Chinese and making the freest use of the *visually assimilated* Chinese characters, has absorbed many of the virtues of the Chinese technique of expression: conciseness, convenience, accuracy, and frequently, a vivid and picturesque phraseology.

Thus an entirely different picture is presented by the Japanese technical vocabulary. Before proceeding to the analysis of the latter, however, a digression on the related problem of the Japanese script would seem to be in order.

In the first place, the use of pictorial symbols, like the Sino-Japanese ideographs, which appeal to the eye rather than to the ear, possesses certain powerful advantages. As I pointed out in my paper mentioned earlier, this is attested by the widespread and growing use of this type of symbolisation in science and technology. The classic examples are, no doubt, mathematics and chemistry. In the case of the former, for example, most of its complex expressions, formulae, equations, etc. are visually grasped and assimilated as a necessary

precondition of interpretation. In a page of ordinary mathematical text one will find these complex "pictographic" expressions interspersed in a "matrix" of ordinary printed material recognizable to all. In dealing with such material the reader constantly shifts from a "phonetic" interpretation of the familiar words of the text--however this may be concealed by the customary speed and skill with which we handle ordinary printed matter--to a "visual assimilation" of the complex mathematical expressions, symbols, etc. In a typical statement like "The functions f(x,y) and g(x,y) are independent if the Jacobian

$$\begin{vmatrix} \frac{\partial f}{\partial x} & \frac{\partial f}{\partial y} \\ \frac{\partial g}{\partial x} & \frac{\partial g}{\partial y} \end{vmatrix} \neq 0",$$

the expressions f(x,y) and g(x,y), and the inequal-

$$\begin{vmatrix} \frac{\partial f}{\partial x} & \frac{\partial f}{\partial y} \\ \frac{\partial g}{\partial x} & \frac{\partial g}{\partial y} \end{vmatrix} \neq 0$$

ity would almost certainly be visually recognized and interpreted by a practised mathematician, without an intervening stage of phonetic reproduction of the sounds represented by the symbols used, f, x, y, g, 0, etc. Almost any page of mathematics will illustrate this same point. Indeed, mathematics has probably evolved so luxuriously and so powerfully largely because of its early recognition and extensive use of a script based on visual symbols.

Remarkably, this is very much what the situation is in Japanese; and there is, in fact, a striking analogy between printed Japanese and printed mathematics. Japanese too uses a mixed

ideographic and symbolic script, consisting of a great mass of borrowed Chinese characters and a small group of purely Japanese phonetic elements for purposes of grammatical exposition. As Sansom (loc. cit. p. 7) puts it: "The Chinese characters (which are pictographic or ideographic) give the skeleton of a statement, and it is clothed in an elaborate grammatical robe of Japanese texture composed of moods, tenses, and other intricacies....", and this is done chiefly by means of the phonetic elements, called "Kana" by the Japanese. This has resulted, it must be admitted, in a weird and difficult hybrid script which becomes even more remarkably mixed when it is used for scientific and technical purposes, for then elements of the European symbol systems are also introduced from mathematics, chemistry, engineering, etc.

However, although it cannot be denied that the complex Japanese script is one of the chief difficulties of the language, it must be born in mind that the use of the Chinese ideographs is entirely in accord with the prevailing spirit and practice of scientific formulation; and is, in fact entirely parallel to our modern and highly successful mathematical script. It is, in fact, by no means far-fetched to maintain that a script based on ideographic or "pictographic" symbols constitutes a powerful release from the prevailing custom which arbitrarily shackles our system of writing to our system of speech, notwithstanding that what is essentially a visual medium of communication is thereby unnecessarily and arbitrarily limited to reproducing speech, the product of an entirely different means of communication. This results in our script losing its most potent and useful quality: that of enabling us to deal much more quickly, conveniently, and directly with ideas, rather than

with "a written symbol of a spoken symbol of the idea". This situation is similar to what we would have if, say, painting were to be restricted to imitating the content and technical forms of music.

However, none of the existing sciences has as yet learned to dispense entirely with ordinary script, and even mathematics still depends very largely on ordinary, everyday language in its customary printed form for purposes of recording and communication. This has resulted, as we have indicated above, in a sort of mixed or hybrid script which partakes of both the phonetic or aural and the visual or ideographic type of linguistic symbolisation. But in so far as the ideographic portion of the Japanese script is concerned, Sansom has well said: "The Chinese character can convey to the eye any meaning assigned to it, irrespective of the sound by which it may be known". This is exactly what our mathematical and other technical pictographic symbols are intended to do. For example, in a statement like,

一般に種類の違ふ二物質を摩擦すると,一方は正に他は負に帶電する……

(*"In general, when two qualitatively different bodies are rubbed together, one becomes positively charged, the other negatively charged".*), the Chinese characters and compounds, as 種類,違,摩擦,負, etc. which, as Sansom said, "give the skeleton of a statement", are capable of immediate visual assimilation and interpretation, permitting the reader, so to speak, to proceed directly to their significance without an intervening stage of phonetic reproduction and interpretation, whereas the purely phonetic elements, asに,の,を,と,はetc., which indicate various grammatical and syntactic

relationships of the ideas and concepts symbolised by the Chinese characters, must be visually recognized and phonetically interpreted to yield their significance in the context.

Fundamentally, the difficulty of the Japanese script stems rather from the historical accident that the Japanese uncritically adopted for use the whole prolix mass of Chinese ideographs which had, in the course of several thousand years of unrestricted growth, developed a luxuriant tangle of unnecessary "undergrowth", so that it contains a multitude of unnecessary duplications and redupli-cations of characters representing essentially the same idea. In fact, the difficulty is very much the same as that which existed, and to some extent still exists, though on a far less massive scale, in the large number of unstandardized symbols in use in modern science and technology. Indeed, the problem became so acute in science and technology as to compel the establishment of standardization committees for the purpose of bringing order out of the growing chaos of unrestricted symbolic expression which, if unchecked, might have led to demoralization of the whole necessary technique of ideographic symbolism so important to mathematics, electrical engineering, chemistry, radio, etc.

Unfortunately for Japanese, however, it has never had a committee on standards to fix the specific meaning of the characters once and for all, at least for the purposes of science and technology. Instead we have the unfortunate situation in which a dozen or more different characters can all have the same meaning, or conversely, the same character can have a dozen or more different meanings. For example 回,廻,迴,旋,週,圍,巡,轉, etc. all mean "to rotate, revolve, turn", and must all be learned because a Japanese author is free to

use any one of these in a text, or as part of a compound expression. When it is realised that this same point applies, to a greater or lesser degree, to the whole Sino-Japanese vocabulary, it can easily be seen what an immense and unnecessary consumption of energy is required to learn printed Japanese. One need only visualise what the situation would be if there were several English terms for every concept in science and technology. But just as one cannot quarrel with the use of ideographic symbols in mathematics, or any other branch of science or technology, so it is impossible to say that Japanese would be simplified if the characters were discarded in favor of a purely phonetic script.

What Japanese, and Chinese, for that matter, needs is to have its script vocabulary pruned, sifted, and refined, so that the many thousands of characters which needlessly duplicate each other's meanings, and which thereby impose such a heavy burden of memorization on the user of the language that for practical purposes the great potentialities of the ideographic or pictographic script are nullified, might be reduced to a reasonable 1000 to 2000 carefully selected elements. In the resulting product of such a systematic refinement and simplification of the crude mass of symbols used, these languages would have at their disposal a powerful, concise, and "universal" scientific script. But as matters now stand, the heterogeneous mass of characters now in use are simply an added source of inefficiency in the language. Yet the fact remains that their use is the one saving element in the whole irrational Japanese language complex, which must not only support an involved and inefficient syntax, but also a wealth of homonyms which would make the technical language practically impossible

to understand if the ambiguities of phonetic reproduction were not immediately resolved by the use of the characters. For, instance, there are perhaps 400 concepts represented in Japanese by the sound "ko"; yet each of these is quickly and accurately identified when represented by a Sino-Japanese character. Thus the quarrel is not with the use of the ideographic script as such, but with its unsystematic, and indiscriminate employment caused by the uncritical absorption of the whole mass of Chinese characters by the Japanese.

The fact of the matter is that the Sino-Japanese characters, and related pictographic symbol systems like those of science and engineering, mathematics, etc. have powerful advantages over the purely phonetic systems not only in greater conciseness of expression, but in an enhanced suggestiveness and broadened field of implication which far transcend the corresponding characteristics of the latter. They have, so to speak, added or enlarged dimensions of form and implication which are lacking in the rigidly phonetic symbolisms. Indeed, it is not going too far to say that the graphical vocabulary of Chinese and Japanese is closer in spirit, technique, and range of implication to the systems of pictographic symbols used by modern science and technology than any other system of writing, ancient or modern. Moreover, this fact opens up the possibility of a new and suggestive field of study--comparative symbolics, as opposed to comparative linguistics. Here "family relationships" would be established not on the basis of the historical or "hereditary" affinity found in linguistic groups hitherto investigated, but on an ideological or psychological affinity implied in similar graphical solutions of particular symbolic formulations. For example, the complex pictograph-

ic symbol  which means a "condenser grounded through a variable resistance" to an electrician, includes the pictographic or ideographic elements signifying "ground" (or verbally "to ground"), "variable resistance", and "condenser", whose meanings are entirely independent of any *phonetic* value attributed to them, yet are immediately apparent and absolutely definite to persons familiar with this script. These highly simplified little pictures of a wire leading to the ground, a coil of wire with an accessory "tap", and a plate condenser respectively are perfectly analogous to the corresponding Sino-Japanese characters, which also convey their meaning through visual rather than phonetic recognition, though native Chinese or Japanese scholars rarely conceive them as purely visual symbols. At any rate both are examples of an ideographic or pictographic script, which points up what I have said elsewhere of the resemblance of a page of printed Japanese to one of, say, electrical theory, or mathematics.

To conclude this not entirely irrelevant digression on ideographic symbol systems, it is worth noting that it was precisely the need to *formulate* the immense mass of new scientific ideas and objects contained in occidental science and technology that impelled the Japanese to commit themselves permanently to the Chinese ideographic script. Up to the end of the 19th century a vigorous movement existed in Japan whose purpose was the abolition of the character script, and its replacement by the socalled "Rōmaji" or Latin script in general use in Western Europe. But soon after the turn of the century it became increasingly apparent to the Japanese that in the Chinese characters they were in possession of a thoroughly satisfactory set of "symbolic building blocks" or elementary picto-

graphic symbols which were able, either singly or combined in groups, to express the new ideas directly, or to supply an adequate equivalent of the new object or concept. Moreover, the use of the characters in combinations of two, three, four, up to seven or eight characters or elements was for practical purposes infinitely extensible, so that as fast as the new technical concepts were confronted, a handy, frequently highly descriptive or suggestive equivalent in terms of the character compounds could be synthesized. It is indeed an interesting fact that the unprecedented revival of the use of the Chinese characters by the Japanese should have been so largely conditioned by the need to assimilate as rapidly and as completely as possible the whole new world of ideas comprising the body of western science and technology which, in turn, had already independently started the development of another set of ideographic symbols for the solution of more or less the same problem confronting the Japanese.

PART II: THE JAPANESE TECHNICAL VOCABULARY

In many ways the Japanese technical vocabulary is a very remarkable achievement, as well as a "sine qua non" of technical expression in that language. In several ways, too, it is indeed superior to our European terminologies: first, in its use of an ideographic script, second, in the fact that many of its terms are more self-explanatory than ours, third, in its use of "functional" terms. Before going into this, however, it is well worth remarking once more that the development of this immense scientific and technical Japanese vocabulary --in little more than fifty years--amounting to many tens of thousands of new terms in the language, and designed to deal with the whole new world of ideas presented by the "fait accompli" of European science, is one of the most remarkable events in the history of language.

Essentially, the procedure of the Japanese in this immense task was to analyse the new technical concept, mechanism, or relationship into what were conceived to be its essential components, then to assign Chinese characters or groups of characters which with varying degrees of accuracy or completeness represented the Japanese conception of the new entity, or of enough of its basic features to identify it. This technique, however, was not really new, since it is exactly what the Chinese had been

*Some of the material in this section has appeared in a restricted technical manual issued by the War Department from material prepared by the author for the U. S. Army Signal Corps.

doing for thousands of years in developing their own terminology--not necessarily technical. What the Japanese did was simply to apply or adapt the existing Chinese technique of coining terms on a gigantic scale, and to a fresh field, after first analysing the new concepts for their basic characteristics, which were what the adopted characters were intended to symbolize. Two points must be kept in mind here: *First*, this vocabulary, though Chinese in the sense that it is built up of Chinese characters, was already so completely "Japanized" as a technique through long practice that the new terminology did not appear at all "foreign" to the Japanese. Sansom (loc. cit. p. 33) puts the matter thus: "The history of the Japanese vocabulary for many centuries after the introduction of Chinese learning (and script) may be summarized as a tale of borrowing from Chinese, commencing with independent words, and continuing on an increasing scale, with compounds. Today the Chinese words in the language are far more numerous than those of native origin". He adds (p. 67), that "The only new feature of interest is the modern habit of forming new Chinese compounds without reference to Chinese procedure"; and, incidently, new characters which, though built up of Chinese elements, are themselves new configurations used only in Japan, and known as "kokuji", or "national characters". Their number is small--no more than 200-300, and they generally have a very specific technical significance, as a specific Japanese unit of measure, or implement, etc. *Second:* since, in formulating the new terms, the basic ideas were, in general, first clearly analyzed and carefully weighed, the individual terms, and the vocabulary as a whole, both appear to be quite rationally and systematically developed, so that the overall characteristics of the

Japanese technical vocabulary are distinctly favorable, or, from the point of view of technical requirements, highly efficient.

Before proceding to a more detailed study of the Japanese technical vocabulary, however, it is advisable to outline a few of the salient features of technical terms. Scientific and technical terms --or better "names"--are all either descriptive, or functional, or both. That is, the name tells us what the thing is, or what it does, or indicates both at once. Accordingly, when we consider the "names" of scientific or technical entities, we find that they reveal two basic types of nomenclature: a) those which describe the appearance, a structural detail, or some more or less striking element in the appearance of the object, as a "gear-driven press", a "laminated" or "leaf spring", "high-speed engine"; b) those which indicate the function of the entity in question, as "insulating varnish", "gear-cutting machine", "steam generator". In addition there is a large sub-group of type a) which describes an object or concept in terms of its manufacture, source of origin, or inventor or discoverer, as "Cottrell precipitator". "lead pipe", "open-hearth steel", "Bessel functions", etc. The great bulk of technical terms in any language belong to one or another of these categories, and the same, of course, is true of Japanese.

Of these, the second group above--the "functional" names--are generally superior to the purely descriptive terms because very often a complicated machine is designed to perform a relatively simple function, as a "planer" among machine tools, or a "pile driver". In such a case a descriptive term might select any one of a multitude of descriptive

or structural details of the machine for the name, leaving unmentioned a multitude of equally important or striking features; but the function of the machine is unique, and characteristic of it alone. Ideally, both elements should appear in the complete name, so that if the basic term is already indicative of a "functional" characteristic of the object, the rest of the name will be descriptive, and if the term is already descriptive, the complete expression will include a functional element; i.e. both structure and function must somehow be indicated in the complete term. For example, "insulating varnish" adds a functional concept, "insulating", to the descriptive term "varnish", while "synchronous generator", reversing the situation, modifies the functional term "generator" by means of the descriptive concept "synchronous". It must be understood that the distinction indicated here is not a rigidly marked one, since, as I pointed out in my paper "Language and Science", to the expert in a given field the structural or descriptive characteristics of a machine and its function are necessarily and indissolubly related. That is, each helps to define the other, so that both merge in an integrated conception in which structure and function or operation are simply correlative phases of a larger conceptual unit embracing both. But for practical purposes of classification of nomenclature, the distinction still has its uses.

In general, it can be demonstrated that the Japanese technical vocabulary definitely favors the "functional" type of name, as opposed to the descriptive. Furthermore, because of its well known capacity for turning practically any "Chinese" substantival construction into a verbal one by suffixing the Japanese verb "suru: to make, do, perform",

as well as because most of the Sino-Japanese characters have both verbal and nominal significance, we find that Japanese comes much closer to the ideal symbolisation of the structural and functional characteristics of technical objects by means of identical root concepts than does any European language. In these respects, as well as in others to be indicated, Japanese possesses a superior technical vocabulary and system of nomenclature which partly offsets the devastating inefficiency of its syntax.

The following are examples of the Japanese predilection for functional terms, where the corresponding English is purely descriptive: "leaf spring" or "laminated spring" is given as 撓弾機 or 撓ばね "ninai bane" or "load-bearing spring", as well as 板弾機 and 重弾機, literally "leaf" and "laminated spring" respectively. Again, "split rudder" (aeronautics) is given as 制動方向舵 or "braking rudder", which is descriptive of its function, as is 飛揚構造 "aerostructure", literally "flight raising or sustaining structure" in Japanese. Similarly "Cottrell process" is given as 電氣收塵法 or "electric dust collection process", etc. This last example is an interesting one as it illustrates the general tendency in technical Japanese to make the vocabulary as specific as possible. As there are a great many technical terms in English and other European languages which simply indicate a personal or geographical name connected with the object in question, or include some other irrelevant element, the Japanese term in such instances is often a definite improvement. For example, this superiority of the Japanese nomenclature is quite evident in the field of mineralogy, where our own arbitrary terms are often replaced by instructive Japanese equivalents: e.g.

"pisanite" becomes 銅綠礬, literally "copper-green vitriol", "tephrite" is 灰色玄武岩 literally "ash-colored basalt", etc. Some other instances of superior Japanese terminology are: 着陸(or水)裝置 "landing gear", depending on whether the plane lands on the ground or alights on water, 隱顯降着裝置 literally "disappearing and reappearing landing gear" for "retractable landing gear" (aeronautics), the very neat distinction indicated in the use of 發電子 for "armature" in electric generators, and 電動子 for "armature" in electric motors, where the first says literally "electricity emitter or producer", the second "electrically motivated rotor"; again 汽約 "wire drawing" (steam engineering) is entirely misleading in English, where the Japanese says more accurately "steam reduction", or "thinning"; similarly, 自働水穿 "steam trap", where, as the Japanese plainly indicates, it is really water which is "trapped," and 集散地 "distribution center", where the Japanese says "assembling and distributing center". This last term, and the Japanese examples for "armature" above are illustrative of the happy faculty both Chinese and Japanese share of being able to make important distinctions between or additions to specific concepts very neatly and concisely because of the compactness of the Sino-Japanese characters, which nevertheless carry a full "charge" of meaning, and a wide range of implication.

An interesting and important group of terms in Japanese (and Chinese) uses the implied synthesis of "opposed concepts" to provide a general notion which includes both the extremes and a multitude of intermediate degrees, as 高低, literally "high-low", for "height", 近遠 "near-far" for "distance", 伸縮 "extension-contraction" for "expansibility", 遲速 "slow-fast" for "speed", 多少 "much-little"

for "amount, quantity, number", 長短 "long-short" for "length", etc.

Then there are whole series of terms in technical Japanese which contain a constant element, and which are generally analogous to corresponding English groups. The following are fairly common: 可, frequently equivalent to the English suffix "-able", as 可變 "variable"; 可動 "mobile", etc., 電氣 "electrical", which enters into a multitude of compounds; 少型 and 豆型 "small type" or "miniature"; 手動(廻,働,回,etc.)"hand operated" or "manually operated"; the important character 材, which appears frequently in structural and civil engineering literature, where it signifies "beam, girder, angle iron, etc.", as 丁-型材 "T-steel", 周緣山型材 "boundary angle-iron" (shipbuilding), etc.; 有効(效) "effective" as 有効高 "effective height", etc; 除, which often corresponds to the English suffix "-proof", as in 塵埃除 "dust-proof", 濕氣除 "water-proof", literally "dust-excluding" and "water (or moisture) excluding"; 當 corresponding to English "per", as in 馬力當重量 "specific weight" (of an airplane engine), literally "weight *per* horse power", 化 -suru, as in 簡單化 -suru "to simplify", 酸化 -suru, "to acidify", etc., 亞, preceding a chemical compound and signifying an "-ous" compound, as opposed to the normal "-ic" compounds, as in 亞砒酸 "arsenious acid", and in corresponding "-ite" salts, as 亞硝酸アンモニュム "ammonium nitrite", etc. In the case of "zinc" and "plumbous", 亞鉛, an inevitable ambiguity has arisen, as in 亞鉛酸鹽, which could be either "zincite" or "plumbite".

Another noteworthy point in Japanese--once again common to Chinese--is the use of the numeri-

cal "classifiers", corresponding to English expressions like "3 *panes* of glass", "5 *yoke* of oxen", etc. For example,軍艦二艘 *~gunkan nisō~* "two warships"; 紙三枚 *~kami sammai~* "three sheets of paper", where the 艘 and 枚 are examples of these "auxiliary numerals", as they are also known. An adequate discussion of these is found in most Japanese grammars, and their use in technology is exactly equivalent to their use in common, everyday Japanese, so they will not be further considered here. However, there is a curious possible connection between them and a group of characters used for specific types of instruments, as 儀, which is generally used in the names of astronomical and surveying instruments like 照準儀 "alidade",六分儀 "sextant", etc.

Problems of Translation.

When we come to the practical question of translating scientific and technical Japanese we find that, over and above the formidable difficulties of the involved and "irrational" Japanese syntax, there are additional problems due to the nature of the Japanese script and vocabulary. The major difficulties here are 1) the complexity of the script itself; 2) Japanese "kana" terms, particularly in the field of chemistry and as used for personal names; 3) the vast number of synonymous terms: i.e. a multiplicity of Japanese terms for a single English equivalent.

Complexity of the Japanese Script. It is quite probable that scientific and technical Japa-

nese is the most complex and difficult script in use in the modern world. It employs not only the whole involved system of Sino-Japanese ideographs, which, indeed, form the backbone of the whole script, but also two purely Japanese phonetic syllabaries with their own peculiar scripts, the so-called "Katakana" and "Hiragana", and in addition the whole tremendously complicated European symbolic script developed for such fields as mathematics, chemistry, and the various branches of engineering and applied science, plus additional fragments like the Arabic numerals, letters of the Greek alphabet, etc. Any or all of these is apt to appear on a page of scientific or technical Japanese, so that from the point of view of the overall complexity of the script alone it is not difficult to see that accurate translation of scientific Japanese is probably the most formidable task in the whole field of linguistic communication. Moreover, the isolated fragments of European symbol systems mentioned above combine in various peculiar ways with Sino-Japanese elements to form Japanese technical terms, which makes the problem of ordering such a heterogeneous mass of material into a "rational" dictionary order extremely difficult, if not impossible.

In this mixed mass of printed material it often becomes something of a problem just to isolate and identify a technical term in a larger context. Here the difficulty stems directly from the overwhelming complexity of the Japanese technical script, for it is equally possible to have technical concepts expressed by the Sino-Japanese characters alone, either singly or in compounds employing up to a dozen or more characters, by the two systems of "kana", by various combinations of elements of these"purely" Japanese ingredients, or, finally,

by various agglutinations and combinations of these Japanese components with fragments taken from the European symbol systems mentioned above, either words, letters, abbreviations, mathematical symbols, etc. Though the great bulk of Japanese technical terms belong to the first category--single Sino-Japanese characters or group combinations of these characters--the others are frequently encountered: e.g. アンペーア回数 "number of ampere-turns" (electricity), 両向き流れタービン "double flow turbine", 逆L型アンテナ "inverted L-type antenna", 板ためロール "plate bending roller", 送電線Π型回路 "transmission line Π-circuit" (el. eng.), 貫Y分岐 "through-Y" (railroading), 三つ組クランク軸 "three-throw crankshaft", etc. In this situation it must be admitted that only experienee and a willingness to experiment with possible combinations can help the translator.

An interesting point in this connection is the use of European letters of the alphabet, and some Sino-Japanese characters, for their pictorial value, as I-, H-, T-, Z- 型鋼(or材) "I-, H-, T-, Z- beams" (used in structural engineering), which sometimes, however, appear as 工,丁,乙型鋼(or材) where pictorially similar characters are used for the same purpose, the Π-circuit example mentioned above, △-結合-△ -connection" (el. eng.), and the author has even encountered Kana characters used pictorially, as への字曲柄 "bell crank".

Another pitfall for the unwary is the occasional use of characters for their phonetic value; e.g. 度 is normally used as a technical term in its own right, meaning "degree, extent, etc.", and it usually adds this element of significance to those terms in which it occurs as final element, as in

速度 "velocity" (literally "degree of speed"), 温度 "temperature" ("degree of heat"), etc. But in 沃度 it is purely phonetic as 沃度カドミユーム "cadmium iodide". Similarly, we find 波來土 read "haraito", or "pearlite" (metallurgy), 侏羅世 "jurasei" "Jurassic epoch", etc. However, this is a minor point, though it must be kept in mind.

Again, the question of *readings* poses a difficult though relatively unimportant problem for the translator of technical Japanese. Aside from the fact that the Sino-Japanese characters have several possible "readings" or "pronounciations" in technical Japanese, there is the added point that occasionally the commonest reading of a technical term is an irregular one. In this case it is generally a phonetic approximation of a European equivalent entirely unrelated to the normal "readings" one would expect from the given combination of characters. Occasionally it is simply an arbitrary vagary of Japanese reading of the characters. Examples of the foregoing are: 喞筒, which might reasonably be read "shokutō", is actually pronounced "pompu", from "pump"; similarly 制動機 is sometimes read "burēki" (brake), 洋刀 is read "naifu" (knife), and 渦輪 "karin" or "uzuwa" is also read "tābin" (turbine). The problem of readings is a difficult one at best, since most of the complex technical terms used in Japanese are seldom, if ever, used in actual speech, but only in the written literature. In many cases the actual reading has never been decided at all, since no one will have had occasion to actually talk about the matter in question, though it might be a well-established concept in the technical literature. At any rate, since the Sino-Japanese characters are ideographic, bearing meanings which are more or less independent

of the actual sound associated with them, this is not a very serious problem for the translator. An interesting example of the variability of Japanese readings is the term 熔接接手 "yōsetsu tsugite" (welded joint), where the same character 接 has two different readings within the same term.

Very serious difficulties are encountered in the extensive use of *kana*. For example, the greater part of the vocabulary of organic chemistry, as well as many proper names are given in kana. Since these are practically all taken from a number of European languages, and since the Japanese phonetic system is deficient in many sounds common to the former, such "kana terms" are often distorted beyond any reasonable chance of recognition. For example, only a person thoroughly familiar with both the vagaries of Japanese and the technical field itself would recognize デウルツエウイーキの理論 as signifying "Drzewiecki's theory", important in the aerodynamics of propellers; and even a simple case like ウエンテ型擴聲機 "Wente's loud speaker" can be troublesome. Another minor source of confusion is the occasional transliteration of Latin or Greek letters, as in テーエス型 "T.S. type", デルタ結合 "△-connection", etc. Moreover, Kana terms are themselves by no means uniform; thus "diesel" is given as ヂゼル or as ディゼル, "valve" as バルブ or ウ"アルウ"; "microphone" as マイクロフオン or マイクロホン, etc. Again, when fragments of European words are taken over literally, as is often the case of trade names for manufactured articles, the translator frequently finds himself up against another blank wall. A good example of this is the word バリコン "barikon", which the translator is so strongly inclined to regard as a possible "balcony", only to find, if he is lucky enough to find it at all, that it is really the kana version of the trade name "Varicon", itself

an abbreviation of "variable condenser". For that matter the translator need not be surprised to find any technical term given in kana, even though Japanese has perfectly satisfactory character equivalents for them: e.g. ベーパーロック "vapor lock" (氣關),スイッチ "switch" (開閉器),カーテン ウォール "curtain wall",(帳壁)

A particularly interesting point in connection with the use of kana is the fact that Japanese chemical terms have generally taken their cue from the German. Hence a chemical term like "isoleucin" will be given as イソロイシン, following the German pronounciation of the Greek prefix *iso-*, whereas a non-chemical term like "isometric", if not given in characters, as might be done, will generally be written in kana as アイソメトリック. Similarly "sulfonic acid" is written スルホン酸, from the German "Sulfonsaure"; and in general the translator of chemical Japanese must keep this fact constantly in mind.

On the whole there is no question but that in the field of science and technology the use of kana presents serious difficulties to the translator, partly because of the differences in the Japanese and European phonetic systems, partly because Japanese is as likely to borrow from one European language as from another, though the bulk of borrowed terms are certainly taken from the English, with German a poor second, except in the field of chemistry. Still, it is difficult to see how the average translator is going to discover that a ベリーゼルング式冷却器 is a "spray cooler", the kana portion being taken from the German "Berieselung" (spray), though he can take heart from the consideration that certainly less than 2% of the kana encountered will be of this rather

baffling type. Even so, single names, as pointed out above, will often be spelled in several ways, as アンペア; アンペーロ, or アンペー for "Ampere", while an example like 波來土"parāito" (pearlite: metallurgy), illustrates how the deficiencies of the kana syllabary, plus the redundancies of English spelling and the attempt of the Japanese to imitate as closely as possible the original sounds often lead to a considerable departure from that original.

But the greatest problem connected with the Japanese scientific and technical vocabulary is the immense number of synonyms, or Japanese equivalents for the same English term. Because of the rapidity with which the Japanese swallowed the whole huge mass of occidental science and technology, borrowing from and drawing upon all European and American sources simultaneously, because of the great number of Japanese working independently in the task of absorbing and interpreting western knowledge, and above all, because of the profusion of Chinese characters available for the portrayal and symbolisation of the new ideas, the Japanese technical vocabulary grew into a dense jungle of equivalent terms. Practically every scientific or technical concept can be, and generally is, expressed in several different ways in Japanese; and since these have equal validity in the eyes of Japanese scientists and technologists, they are all equally apt to appear in the literature. I do not believe it is an exaggeration to assert that the Japanese scientific and technical vocabulary has between two and three times as many terms to cover the same range of ideas as does the corresponding vocabulary of a European language such as English.

It is true that technical English is likewise plagued with the problem of unnecessary duplication

of terms for the same entity, as, for example, "angular momentum" and "moment of momentum", "torsion" and "twist", "voltage", "potential", and "electric tension", etc. But whereas this is the exception rather than the rule in English, the situation is reversed in Japanese. For example, there are at least thirty different ways of writing "nut" in Japanese, which in this instance too takes its cue from the idea of "female screw" or "Schraubenmutter" of the Germans. Thus they will use any of the following combinations for this one simple object:

雌牝女母メ } "female" or "mother" x { ねぢ 螺子 螺子 螺旋 捻子 捻子 } "screw"

or again, for an equivalent of "to raise, lift, elevate, draw up" Japanese can use any one of the following compounds:

引曳抽 x 揚上扛擧

where twelve possibilities are indicated, and doubtless many more are possible. These are, of course, extreme examples, but the phenomenon is very generally true throughout the whole of Japanese science and technology.

When we consider the matter more closely, however, we find that the bulk of Japanese technical

synonyms or equivalent expressions can be grouped under four or five headings: 1) terms which differ only by a trivial substitution of one element of a complex term for another closely related character or group of characters; 2) those in which kana replaces characters or groups of characters with equivalent meanings; 3) those in which the multiplicity of equivalent terms is due to the fact that Japanese generally has several characters or groups of characters which express the same idea, any or all of which may be used interchangeably in a technical term; 4) those in which the multiplicity of equivalent terms and expressions derives from the fact that in technology the same object or entity can often be regarded from several points of view; 5) the large number of abbreviated and variant forms of the characters, which are sometimes so different in appearance as to amount to new symbols. We will consider these points in order.

1) Terms which differ only by a trivial substitution of one element of a complex term for another character or group closely related in meaning or implication. The following groups list those most frequently interchanged:

a) 型,形,式,法 meaning "form, type, shape, model, method;

b) 器,機,具,計,器具,装置,機械,械 meaning "tool, device, machine, apparatus, equipment, instrument, engine, mechanism";

c) 性,質,状,態,状態,式,剤 meaning "of such a nature, possessing such a character, of such a type or condition". This group is related to group a), so that members of each are sometimes interchanged.

d) 製,製造 "made of, containing";

e) 度,程,高,程度 "to such a degree, so much, to that extent";

f) 計,規,儀,計器,計具 "instrument, gauge, measuring device";

g) 中,内 "in, within, among, inside, etc.";

h) 附,付,取附(付) "attached to, equipped with, possessing, fitted with";

i) some purely grammatical elements, as 的,の,な(る), etc.

In addition to being interchanged quite freely within their groups, these elements are often omitted altogether as not essential to the meaning of a term. The commonest omissions are perhaps the grammatical elements, though most of the above can be left out in many instances. Accordingly, the translator should memorize them, with the understanding that a term containing one of them as a constituent element would retain about the same significance without the character (or group) in question, or with equivalent members from the same group substituted for the first; i.e. he must be prepared either for their complete omission, or for replacement by related elements.

Besides the above, there are many others not quite so frequently encountered, such as 化 "to change, transform, alter, turn into, treat with", which is very common in chemical Japanese, 上 "on, above, at", etc. To these might be added negative or "privative" terms, in which the negative element may occupy either of two positions; but this point will be reconsidered in greater detail under 3).

In illustration of the preceding discussion the following examples are recommended to the attention of the student as representative of the class of terms under consideration: for instance, in the case of a term like "Sperry stabilizer", one might find スペリ(型,形,式)安定(儀,装置), in which any

one of the elements in the brackets might be used, or in the first group omitted altogether; e.g. スペリ安定儀,or スペリ型安定装置, etc. Similarly, we have 熔接(法,方法) "welding", 電解(質,液,性)検波(器,器具,装置) "electrolytic detector". 石鹸(製造用)機(械) "soap-making machinery", 丁(字型)軌條 "T-rail", 工(字形)鋼(材) "I-beam", 枸櫞酸(化)曹達 "sodium citrate", 無機(態)カリ "inorganic potassium", 高温(度)計 "pyrometer", 層(狀,態)炭 "striped coal", 軍(用,的,の,的の)飛行機 "military airplane" 指向(型,形,式,性)空中線 "directional antenna", 機械(的)通風 "mechanical ventilation", 鐵(製,製造)器 "ironware", 陸(上,飛行)機 "land plane", 坑(中,內)製炭 "charring pit charcoal", 液(狀,態,化)アンモニヤ "liquid ammonia", etc.

More or less closely related to this is the question of kana elements which appear chiefly as inflectional elements of words (chiefly verbs), and which are as often omitted as not: e.g. 引[つ]張[り]棒 ("hippari bō") "tie rod", 接[ぎ]手 (tsugite) "joint, union, coupling, connection", 取[り]外[し]難(or難脫式)プロペラ翼(torihazushi (or *ridatsu-shiki*) puropera-yoku) "detachable propeller blade", etc.

2) Terms in which kana replaces characters or groups of characters with equivalent meanings, as in the following instances: 板ため(or橈)機 "plate bending machine", the examples cited under "nut" above, ポンプ for 喞筒 "pump", グリッド or 格子 for "grid", 鐵筋コンクリート(or混凝土) "reinforced concrete", トルク and 捻力 for "torque", ピストン,活塞,or吸錞 for "piston", ハンダ,盤陀,or鑞 "solder", very many chemical terms (chiefly from inorganic chemistry, most organic terms being in kana), like クロリカリ(鹽化加里) "calcium chloride", 酯酸アミドorアセタミド "acetamide", ボルト,螺釘,or繫釘 for "bolt", ベクトル,ヴエクトル,向徑, or有向量 for "vector" (physics), カム(歪輪) "cam" ぜんまい,ばね,發條,or

彈機 for "spring", 氣 or ケ as in 水ケ (氣) "watery, vapory", etc.

3) Terms in which the multiplicity is due to the fact that Japanese generally has several characters or compounds (groups of characters) which express the same idea, any or all of which may be used interchangeably in a technical term. This is a major source of the needless multiplication of equivalent Japanese technical terms, the differences in terminology arising here from the multitude of equivalent Sino-Japanese characters or compounds of characters: e.g. (聯 or 連) (結, 絡) 桿 (杆, 銲) "connecting rod", (定, 恆, 常, 不變, etc.) (容, 積, 容積) 比熱 "specific heat at constant volume", in which any one of the combinations of characters or groups of characters formed by taking one element from each of the groups in parentheses all mean "constant volume", so that one might have 定容比熱, 恆積比熱 etc. thus twelve synonyms; or again, (發動機, 機械機關) (捻力, 捩力, 扭力, 廻轉率, トルク, etc.) for "engine torque", (相等, 相當) (桁, 梁, 構, 桁構) "equivalent girder" (冷却, 冷凍, 冷, 凍) 鰭 "cooling fin", 補 (正整, or 償) "compensating", as in "compensating winding", compensating gear", etc., the various terms for "screw" mentioned previously, 負荷, 荷重, or simply 負 or 荷 for "load", 壓 (縮, or 搾) "compression", 軸 (受 or 承) "bearing", many characters for "box", as 箱, 函, etc. which are all interchangeable in various compounds like "caisson" 潛函, etc., a multiplicitv of negative forms: 不, 非, 無 as in (不, 非, or 無) 回 [廻] 轉運動 "irrotational motion" (aero-and hydrodynamics), (不, 非, or 無) 抗力材 "non-structural member" (aero), 垂 (法) 線 "normal" (geometry), 原 (起) 點 "origin" or "point of origin", 接 (合 or 手) "joint, connection", etc. There is also a large number of what might be called "inversions". In this last instance the Japanese is simply free to

reverse the order of a compound term without thereby changing its meaning; as 限時 or 時限 "time limit", 填充 or 充填 "to load, fill", 搖動 or 動搖 "vibration, oscillation", 回轉 or 轉回 "rotation", 降下 or 下降 "descent, fall", etc.

In connection with this last point it is also worth noting--though this is rather a grammatical than a terminological change--that negative or privative terms can be expressed in several ways which differ by changing the position of the symbol of negation, as in (無尾or尾無し) 飛行機 "tailless airplane", (無曲軸 or 曲軸無し) 發動機 "crankless engine", etc. Similarly, in the case of many compounds where a verb governs an object, either the verb can precede the object, or the object precedes the verb, as in 吸熱器 or 熱吸器 "heat absorber", 擴孔試驗 or 孔擴試驗 "flaring" or "drifting test" (piping), etc. Here the student will have no difficulty in recognizing the first of these as a typical Chinese construction, the second as an equally typical Japanese word order.

4) Terms in which the multiplicity of equivalent expressions derives from the fact that in science and technology the same thing can often be regarded from several different points of view. This often leads to radical differences in the literal significance of the Japanese and English terms for the same entity: for example, the Japanese often say 有効高 "effective height", where we have "effective depth": similarly, Japanese has 繼从鑽 "connectable bit", where we say "detachable bit". 落下瓣 "drop valve", for our "lift valve", 壓縮性失速 "compressibility loss of speed" for our "compressibility burble", 低壓實驗室, literally "low pressure experimental room", for our

"altitude chamber" (aeronautical engineering), 銃型寫眞器 literally "gun type camera" for our "camera gun", (同,等,無,不,非) 極化合物 "homo-" or "non-polar compound" (chemistry) 飛揚構造 "aero-structure", 薄計 "thickness gauge" (literally "thinness gauge"), 撥彈機(發條) "leaf spring", 氣密度 "permeability" (referring to the rate at which gases diffuse through balloon fabric); again, in speaking of electric cable the Japanese calls the "lay ratio" the 撚込率 or "twist-advance rate", which is certainly more illuminating than the English term, 鐵葉板 "tin-plate", where English leaves out the word for "iron", Japanese the character for "tin". It is worth observing that these Japanese formulations are at least as "reasonable" and as accurate as their English equivalents. This same general fact has already been touched on, though from a somewhat different point of view, in the foregoing discussion of "functional" and "descriptive" names.

The two preceding classes of Japanese technical synonyms provide by far the great bulk of Japanese "multiple terms". Largely because of them, the translator of scientific and technical Japanese must keep this major problem of Japanese synonyms constantly in mind. He must be prepared at all times for the substitution of an equivalent or closely related Chinese character or group of characters for another, or for a totally different character or combination of characters which treat the same object from a different point of view. In other words, he must be prepared to deal with ideas as well as with "words", and he must never lose sight of the possibility that the same idea can generally be expressed by more than one Sino-Japanese character or group of characters, or that the same object or scientific concept can generally be

interpreted from more than one point of view, and so receive more than one formulation.

The reverse of this problem of synonyms in technical Japanese, the case where a compound has several English equivalents, is far less frequent or important. Some examples of the latter are 開閉器 "switch" (electric) or "shutter", 線路 "railroad line", "route", "communication line", etc.

5) The final source of difficulty, and a prolific source of reduplication of Japanese technical terms, is the large number of abbreviations and script variants used in the field of science and technology. For example, 壓 "pressure" often appears in the abbreviated form, 圧 and in this form will enter into many compounds; thus 圧縮図 "pressure diagram" (instead of 壓縮圖) where the third character 図 is also abbreviated. There are many such instances, some of the commonest being 台 for 臺 "stand, base", 応 for 應 "to apply", 円 for 圓 "circle 双 for 雙 a "pair, double", 体 for 體 "object, body", etc. Translators will find a fairly complete coverage of such abbreviations in Arther Rose-Innes' "Beginner's Dictionary of Sino-Japanese Characters", which is a very useful volume in several other respects as well. Some additional examples of the use of abbreviations are 楕円 for 橢圓 "ellipse", 偶ー for 偶冪 "even power" (algebra), etc.

A different sort of abbreviation is fairly common in chemistry, involving expressions like 硫安 instead of 硫酸化安母紐謨 for "ammonium sulphate", and related terms in all fields in which a 及,並,合成etc. is omitted, as in 離着陸装置 "landing gear" (aeronautics), 順列(及び)組合"permutations and combinations" (algebra), 弧光(合成)抵抗爐 "resistance furnace" (electricity), etc.

Script variants are characters closely related to the abbreviations in some respects, but differing from them in that they are not necessarily formed by simply omitting a part of the original character, but may contain new elements which, however, leave the original meaning substantially unchanged. A good example of this is the group-回,囘,廻,廻,迴, and 迴, all with exactly the same reading ("kai, meguru") and meaning ("to rotate, revolve, go round"), but differing slightly in the nature of the elements making up the character, and hence found in different places in a Japanese dictionary. Thus in referring to a "rotating magnetic field" the Japanese electrician will use any of the following expressions: (回,囘,廻,廻,迴,or迴) 轉磁界. Other examples of this are直捲 (or巻) "direct winding" (electrical machinery), 鍔 (付,附,接,継) 管 "flanged pipe", etc.

An important group of script variants comprises a series of characters in which a change of the radical has been used to indicate a change in the physical nature of the material under consideration. For example, 金 "metal" often replaces 木 "wood" in a large group of characters to indicate that metal is used in place of wood in a "modern version" of an older implement: 鉾 "metal rod", in place of 桿,鈑 "sheet metal" or "plate" in place of 板, a "wooden plate" or "board", 鎚 "hammer", from 槌,鉢 "metal trough" from 樋 "wooden trough", etc. This same metal radical replaces many others besides wood, however, as 鎔 "to melt" or "fuse" metals, from 溶 "to dissolve", where 金 replaces 水 "water". Other examples in this category are 鐶 "metal ring", from 環;錬, 練,糠,煉,湅 all meaning "to refine, purify, work over", but where 錬 is used to indicate the "refining of metals", 練 the "glossing" of silk, etc.

Similarly 鎳 "wire" from 線,鋼索"wire rope" from 索 (ordinary rope), are illustrative of the point under consideration. Again,鈮,砚,坭,泥 all signify some sort of "refuse" or waste material, but the first, with the metal radical, indicates "slurry", a type of waste product found in certain metal refining processes, 砚 and 坭 indicate "muck", as the term is used in excavating work, 泥 signifies ordinary mud, etc. Similarly 屑 and 碎屑 are used for ordinary waste or rubbish and "muck, or rock scrap" in the technical sense respectively.

It is interesting to note that the Chinese have used this same procedure in coining characters for the "names" of the chemical elements. As a result the physical nature of an element is immediately apparent to a Chinese from the composition of the character used to indicate it, as, for instance, the gases 氦 helium, 氖 neon, 氩 argon, 氙 xenon 氪 krypton, etc., where the common element 气 in all indicates the existence of a gas. Similarly, elements which are liquid all have the 水 radical, metals have the 金 radical, etc. as part of their "names." This has been very well written up in an article in Scientific Monthly for July, 1942 by Prof. R. Spooner: -"Chinese Chemical Terms". The Chinese names of the chemical elements are not used by the Japanese, who prefer to use phonetic kana terms entirely lacking in the explanatory features of the Chinese characters.

A smaller group of characters illustrating a somewhat similar principle comprises a group of nautical terms for parts of a ship, as 艏 "bow", from 舟"ship" and 首 "head", 艉 "stern", from "ship" and 尾 for "tail", 舷 "starboard", with 舟 and 右 "right", 舷 "port", similarly formed with 左"left", etc.

There appears to be no ready solution of the problems connected with abbreviated forms of characters, script variants, and similar odds and ends except experience in recognizing the members of such groups. They are mentioned here simply to apprise the student of the existence of these "anomalous" elements in an already hypercomplex script, so that he or she will learn to expect a wide variety of departures from ordinary usage in technical Japanese.

A final point in connection with the Japanese technical vocabulary is the occasional assumption of specific meanings by single characters in a given field or context; e.g. 機 often indicates "aeroplane" in aeronautical literature, in which case it is an abbreviation of 飛行機 or 航空機. Similarly 傘 is used for 落下傘 parachute", 脚 for "undercarriage" or "landing gear", etc. Again, 窠 (nest) is sometimes used for "socket" in electricity. These instances are entirely similar to corresponding English expressions, where the same process of "specialization" has operated to give specific technical meanings to more general, everyday terms.

Summing up our study, we find that scientific and technical Japanese reveals thoroughly contradictory characteristics in so far as its "efficiency" as a means of communication is concerned. On the one hand its technical vocabulary, either borrowed from or based on Chinese models, is found to be highly efficient, accurate, and "functional", whereas its syntax or grammatical structure is, from the point of view in question, highly irrational and inefficient. An interesting problem would be an appraisal of technical Chinese along

the lines indicated here for Japanese. I believe such a study would reveal the former to possess all the virtues of the Japanese technical vocabulary, and few, if any, of the vices of the Japanese sentence structure; in which case it would have to be acknowledged as potentially one of the most effective mediums of scientific and technical communication in existence. Such an inquiry must, however, be reserved for a future date.